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REVIEW OF INSUFFICIENT POWER SUPPLY AND EFFORT TO PROMOTE RENEWABLE ENERGY TECHNOLOGIES IN GHANA.

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ABSTRACT

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Ghana has been experiencing erratic power supply for few years now. The objective of this study was to find out the causes of low power production in the country, reasons hindering the use of available renewable energy resources, and to suggest solutions in achieving a clean and sustainable energy (power) generation to meet the country's increasing energy demand.

This study was a qualitative research. Information in this study was retrieved from reliable sources that have similar interests in finding solutions to Ghana's power challenges. The statistics was first hand information retrieved from reports, articles and journals from major power production sectors in Ghana and the world.

The results of this study demonstrated that apart from hydro, Ghana has very high solar and wind energy potentials that could be used to generate large scale electricity, enough to compensate the increasing demand of electricity power if proper and effective measures are taken.

Keywords - Hydropower, erratic power supply, sustainable energy, Power demand, and peak demand.

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LIST OF ABBREVIATIONS

OECD - Organization for Economic Co-operation and Development

GDP - Gross Domestic Product

GHp - Ghana pesewas

MW - Mega Watts

KWh - Kilo Watts Hours

PV - Photovoltaic

OTA - Office of technology assessment

GDP - Gross domestic product

VALCO – Volta Aluminum Company

GSS - Ghana statistical service

UNEP - United Nations Environment Program

SWERA - Solar and Wind Energy Assessment

NREL - National Renewable Energy Lab

MSD - Meteorological Service Department

VRA - The Volta River Authority

ECG - Electricity company of Ghana

GRIDCO - Ghana Grid Company Limited

NED - The Northern Electrification Commission

PURC - The Public Utility Regulation Commission

GNGC - Ghana National Gas Company

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IPP – independent power producers

PEF - Private Enterprises Foundation

CFLs – Compact fluorescent lamps

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1 INTRODUCTION

A hundred years have passed since the time when man lived in the world of darkness where there is no direct source of light instead of the sun during the day and the moon and stars during the night. Then along came fire and everything changed. People begun to love fire and its usage but also dreaded its dangers. Since then, many discoveries and its inventions were made that involved electricity which has become an essential part of our daily lives. Due to radical change in technology, people have become more and more dependent on electricity and its uses. Electricity is important because it helps make our lives easier. It is the lifeblood that flows through our electronic gadgets making them work.

In today's world, nearly every aspect of our lives depends on using energy. Our access to safe and reliable energy enables our society and economy to work, grow and prosper. Therefore, one must understand how energy drives our economy, what it costs and how several organizations are working to solve energy poverty around the world. The energy industries are changing as they adapt to broader issues, such as the growing population, climate change, government policies and new technologies such as smart meters and grid.

Ghana, officially called the Republic of Ghana, is a sovereign multinational state and a unitary presidential constitutional democracy, located along the Gulf of Guinea and the Atlantic Ocean, in the sub region of West Africa. Ghana has a land area of 238,535 km^2 and a population of approximately 27 million, from a variety of ethnic and religious groups. It became the first African nation to declare independence from European colonization in 1957 and is one of Africa's most developed countries, performing favorably in indexes of governance, stability, peacefulness and human development by regional standards. Its economy is the ninth largest on the African continent by purchasing power parity and nominal GDP and is one of the fastest growing in the world. Among the abundant availability of other energy resources such as hydrocarbons and biomass, Ghana is also well endowed with renewable energy resources particularly solar and wind

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energy resources. Solar radiation levels are estimated at about 4-6 KWh/m^2 and average wind speed along the coastal areas is also estimated at 5 m/s. Despite the fact that Ghana has been endowed with the widest range of energy resources that far exceed its energy requirements, Ghana's power sector still remains severely undeveloped and energy consumption in general and electricity consumption in particular is relatively very low.

The Ghanaian economy continues to date, experience the very severe energy crisis that hit the entire country. The first of such experience since the Akosombo hydro dam was commissioned in 1965 (i.e. the first electric power plant in Ghana) was in 1983 – 1985 followed by 1998 – 2000 and then in the period 2006 – 2007 and the current crisis which started in 2012 to date. The uniqueness of the recent case is the longest period that the nation has to endure, and involves rotating load shedding programs./39/ Unlike the previous power crisis which lasted less than two years, the current situation has persisted for over three years and is still counting as there appears to be no end in sight.

1.1 Objective of the study

The purpose of this study was to find out what were the main causes of the low power production in Ghana, reasons that hinder the use of the available renewable energy resources, and to suggest the solutions in order to achieve clean and sustainable energy (power) generation to meet the Ghana's electricity demand.

1.2 The research question

This research will critically look into the following questions to see as to what Ghana needs to do to meet and improve upon the country's energy production.

1. What are the main causes of the insufficient energy production in Ghana?
2. What impact does energy (electricity) has on the output of industrial development of Ghana?
3. What other energy resources can be used to improve electricity supply in Ghana?

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1.3 Research method

In this work, qualitative method was used as desktop research. Informations, facts and figures were collected from Ministries of Energy - Ghana, Ghana statistical service, reports made by the major sectors of Ghana's power generations, articles and journals made by independent organizations that have common interest in the power sector of Ghana and other individual studies that relates to the success of electricity production worldwide.

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2 IMPACT OF ENERGY IN ECONOMIC DEVELOPMENT

2.1 Economic development

“Economic development is a policy intervention achieved with aims of economic and social well-being of people”./5/ Economy development involves areas such as environmental sustainability, provision of social infrastructure, development of human resources, health safety, education, etc. These are achieved by the effort of political leaders to promote the standard of living of the society which is intended to increase the income by individuals to attain a standard of living equal to that of other industrialized countries.

According to Investopedia dictionary, a developed economy refers to a country with a relatively high level of economic growth and security. Some of the most common criteria for evaluating a country's degree of development are per capita income or gross domestic product (GDP), level of industrialization, general standard of living and the amount of widespread infrastructure. Increasingly other non-economic factors are included in evaluating an economy or country's degree of development, such as the human development index which reflects relative degrees of education, literacy and health./29/

Many industrialized nations focus strongly on the need for qualitative measures for economic development. These measures usually refer to adoption of new technologies, transition in economic based, general improvement in the living standard of the society. The need for energy to help development is vital in developed countries economy. Increasing energy consumption has long been tied directly to economic growth and improvement in human welfare. However, the focus point on this theory will be to access the energy sector of the developed economy since energy provides services to meet many basic human needs, particularly heat, motive power (e.g. water pumps and transport) and electricity. Businesses, industries, commercial and public services such as modern healthcare, education and communication are highly dependent on uninterrupted and constant energy supply but meeting the energy demand thus also present a significant challenge. However, there are many technological options available to provide the energy required. The

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availability of adequate finance is one of the main challenges in meeting current and future demand for energy in developed economy. The current sources of energy finance in developed countries includes governments, multilateral institutions and private investors./36/

2.2 Main and indicated differences between developing and industrial countries

2.2.1 Social

Studies shows that /35/ the life expectancy of citizens in OECD countries are longer than those in the developing countries thus, (76 years, as compared with an average of 62 in developing countries). This is largely due to lower infant mortality rate (9 per 1000 live births compared with 71 in developing countries). A much larger share of the population in the industrial countries have access to secondary and higher education and a better healthcare than those of the developing countries.

2.2.2 Economic

Average per-capita incomes (expressed in purchasing power parties) are more than eight times higher in OECD countries than in the developing countries. This variation of levels in income reflects the major differences in economic structure, particularly the higher share of agriculture in total production in the developing countries. Population growth is more rapid in developing countries. It is estimated to double by 2040 while the population of the industrial world will increase by 15 percent over the same period.

2.2.3 Energy

OTA /35/ further explains that, the per capita consumption of commercial energy (coal, gas, oil and electricity) in the OECD countries is on average 10 times higher than in the developing countries. On the other hand, commercial energy consumption is increasing much faster in developing countries.

2.3 Challenges of energy in developing countries

Unconstrained access to safe, clean and reasonably cheap energy supply is essential for meeting the basic needs of human society and for supporting economic

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growth. As number of studies confirm, there is a direct link between per capita energy consumption and human well-being. The link is particularly strong for non- OECD countries with a human development index value of less than 0.8. Very few countries with per capita energy use of less than 2 tons of oil equivalent have human development index score of more than 0.7./27/ Therefore, providing the energy services needed to sustain growth and, conversely, avoiding a situation where lack of access to such services constrains economic development, remains a central policy objective for all nations./10/

The energy problems of the developing countries are both serious and widespread /15/. Lack of access to sufficient and sustainable supplies of energy affects as much as 90% of the population of many developing countries. Some 2 billion people are without electricity. A similar number remains dependent on fuels such as animal dung, crop residues, wood and charcoal to produce heat and to cook their daily meals. Without clean and efficient energy, people are undermined in their efforts to engage effectively in productive activities or to improve their quality of life.

2.4 Constraints in developing countries major energy supply

According to the U.S Congress, Office of Technology Assessment, developing countries will face major difficulties in tripling energy supply over the next 30 years. The first is the widespread inefficient production and use of traditional energy sources, such as fuel wood and agricultural residues which pose economic, environmental and health threats./15/

The second is the significant obstacles which include financial constraints, difficulties in increasing biomass fuel supplies, institutional policy factors and environmental impacts.

2.4.1 Financial constraints

Producing energy in commercial quantities involve both domestically produced and imported supplies. Almost all the developing countries in most cases rely on imported oil for almost all of their commercial energy needs. Further increase in

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these energy imports eventually impose a heavy burden on limited foreign exchange resources which may already be under pressure because of debt service payments. Supply of infrastructure and energy facilities such as electricity generating stations and petroleum refineries are highly capital intensive, placing major demands on the scarce supplies of both domestic and foreign resources available for capital investment. U.S Congress, Office of Technology Assessment /36/, states that, the World Bank estimates that investment of $125 billion annually (twice the current level) will be needed in developing countries to provide adequate supply of electricity.

2.4.2 Biomass supply constraint

Although there have been rapid rates of urbanization in the developing world, almost two third of the total populations in poor nations live in rural areas. These populations mostly depend on biomass fuel to produce their energy with some rural electrification where available and small but vital quantities of petroleum products for irrigation and transport. The request for biomass fuels, especially fuel wood will continually increase to meet the domestic needs of the urban and rural industries. An estimated one-third of the population of developing countries now faces fuel wood deficits and will increasingly rely on crop waste and animal dungs to meet their energy needs.

2.4.3 Environmental degradation

The production of energy and its use plays a major role to the increase rates in environmental pollution. The combustion of gas or oil in stationary sources such as electric generating units, factories and households also contributes through emission of toxic gases such as particulate, carbon monoxide, nitrogen oxides, etc. Non-fossil energy source such as hydroelectric also causes environmental damage. The process of dam construction results in loss of human settlement, fish production, forest, wildlife habitat and agricultural lands and species diversity. The dam also disrupts downstream flows of water and nutrient-laden sediments.

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2.5 Role of electricity in economic growth

Study of the link between an energy sector and an economic development has been ongoing since the middle of the 19th century. However, the interest in the link was later stimulated by the energy crisis of the 1970s that saw the increase of the study of energy cost of the production process and the subsequent effect on the industry and the economy as whole.

In today's world, almost every country's economic growth and prosperity depend on having an adequate supply of reliable and affordable energy. A country's population, geographic size, industrial diversity and abundant energy resources make it both a major producer and a major consumer of its energy and this in turn contributes significantly to the country's national economy. Energy has been the oxygen of an economy, "without heat, light and power you cannot build or run the factories and cities that provide goods, jobs and homes, nor enjoy the amenities that makes life more comfortable and enjoyable."/19/

Energy forms the life blood of the world economy as it is an essential input to producing almost all of the goods and services of the modern global economy at large. It contributes to economic growth directly as it creates jobs and value associated with extracting, transforming and distributing of energy. Furthermore and more importantly, this sector's activities relate to and strengthen the rest of the economy as energy forms an input for almost all production processes of goods and services. Supply interruptions of many sources of energy are known to have a great impact as they can harshly impact the economies of all countries. This is because lower energy prices result in increasing disposal income for consumers and lowering cost for firms. The resulting improved profit margins for firms and higher disposal income for consumers provide incentives for accelerated rate of growth./31/

Energy plays an important role in assisting to achieve the Millennium Development Goals adopted in the United Nations Millennium Declaration. According to the Inter Academy Council (IAC) these goals and the potential contributions of energy services are summarized below: /29/

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2.5.1 To halve extreme poverty

Access to energy services facilitates economic development-micro-enterprise, livelihood activities beyond daylight hours, locally owned businesses which create employment. Low unemployment rate is good for both the individual and the country as a whole. The social and psychological effect of low unemployment rate cannot be totally ignored as high unemployment has been linked to psychological and physical disorders, divorce, suicide and crime./4/

Employed workers feel better about their situation and can relatively afford to spend within their means. With low unemployment rates, workers can demand higher wages and feel more secure in their jobs. The economy benefits from increased activities and the government receives more tax as a result of that. The tax generated can be spent on schools, hospitals, education and other social infrastructure. Low unemployment tends to have positive effects on social divisions in the country./4/

2.5.2 To reduce hunger and improve access to safe drinking water

Sustainable development recognizes that growth must be both inclusive and environmentally sound to reduce poverty and build shared prosperity for people today and for future generations. At the same time, growth patterns have left hundreds of millions of people behind: 1.2 billion lack access to electricity, 870 million are malnourished, and at least 748 million are without access to clean, safe drinking water. While efforts to expand access to safe drinking water are on track to achieve this target in most regions, 2.5 billion people still lack access to improved sanitation./*41*/ Energy services can improve access to pumped drinking water and provide fuel for cooking

2.5.3 To reduce child and maternal mortality and to reduce diseases

Energy is a key component of a functioning health system, contributing, for example, to lighting operating facilities, refrigerating vaccines and other medicines, sterilizing equipment and providing transport to clinics. Energy helps

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to provide better healthcare which increases life expectancy of the ordinary citizens in a country.

2.5.4 Achieve universal primary education and to promote gender equality and empowerment of women

Energy services reduce the time spent by women and children on basic survival activities (gathering firewood, fetching water, cooking, etc.): lighting permits home study, increase security and enables the use of educational media and communications in schools, including information and communication technologies.

2.5.5 To ensure environmental sustainability

Improved energy efficiency and use of cleaner alternatives can help to achieve sustainable utilization of natural resources as well as to reduce harmful emissions that protect the local and global environment./10/

A sustainable growth of an economy mostly depends on the growth and performance of a country's energy and electricity sector. In order to attract, retain and expand the growth of an economy, there should be various policies that assist to promote a secure, competitive and a reasonable priced energy supply. These include policies that improve energy supply reliability and maintain its sustainability in developing energy related issues and also policies that support reducing energy costs to consumers.

Energy has great impact on an economy. It influences economic development by providing capacity for large investments. Investment in the energy sector can stimulate national enterprises while energy price is also pervasive to all sectors and influences the competitiveness of the country. The demand for energy increases as both agricultural and industrial processes increases.

Formulating strategic goals for development of energy systems and identifying the avenues to achieve those goals for sustainable development are the primary objectives of the energy sector in economic development. One must clearly note

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that, the energy sector is mainly responsible for the provision of energy to a country through various means as the demand for energy grows.

2.6 Electricity generating sources

Almost every country in this world has two or more resources that can be used as a source to generate electricity. Energy resources fall into two categories, thus renewable and nonrenewable.

2.6.1 Renewable generating resources

Renewable resources are fairly easy to replace. These resources are not subjected to depletion in a human timescale. These sources include the sun's rays, waves, rivers, tides, wind, biomass, heat from radioactive decay in the earth's core and water stored behind dams in lakes and reservoirs. Electricity can be produced using several kinds of renewable resources.

2.6.2 Wind energy

Wind can produce electricity in regions where steady wind blow. Giant wind turbines capture the wind's energy and use it to power generators. Wind energy converts the energy of wind into a useful form of energy, such as using windmills for mechanical power, wind pumps for water pumping or drainage. This form of producing energy produces no pollution.

2.6.3 Biomass

This is formed from living organisms such as wood or agricultural wastes. Biomass can be burned to produce electricity or be converted to a gas or used for fuel.

2.6.4 Solar energy

This form of energy is derived from the sun. Solar cell changes the radiant energy of the sun into electricity energy. Solar panels or modules placed on a rooftop can supply electricity to a building below. Solar energy is mostly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include using photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques also

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include orienting a building to the sun, selecting materials with favorable thermal mass or light dispersing properties.

2.6.5 Hydroelectricity

The energy contained in falling water is used to spin generator turbines to produce electricity. This form of energy little pollution but does not ruin the water. The water can still be used for other purposes. This form of producing power does not cost more than using fossil fuel. Hydro power faces a controversy when classifying it as a renewable resource. It is produced from elemental, natural and recurrent resources such as rainfall and snowfall. Its fuel is not depleted during the production of electricity. Environmentalists however say the construction of dams as well as the change of course in rivers causes irreversible damages to wildlife and the ecosystems./17/

2.6.6 Geothermal energy

This energy form uses hot water or steam from deep beneath the earth's surface to produce electricity. It is environmentally friendly. Geothermal power is produced when enough heat rises close to the surface of the earth and heats underground water causing steam that can be used at steam-turbine plants. Geothermal power plants do not produce emissions of sulfur dioxide, carbon dioxide and nitrogen oxides, unlike coal generating power plants.

2.7 Nonrenewable energy resources

These resources come out of the ground as liquid, gases and solids. They are crude oil (petroleum), natural gas, propane and coal. These resources are considered fossil fuels because they are formed from fossils (remains or impressions of organisms of past geologic ages). These resources can be used up (cannot be replenished in a short period of time).

Many power plants use fossil fuels. The fossil fuel is burned to produce heat, which is used to make steam. The steam is then used to turn the blades of a turbine coupled to a generator to produce electricity. The availability of fossil fuels are not dependent upon the weather. Some major problems of using fossil

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fuel to produce electricity are that, they cause pollution and need to be mined from the earth.

Some power plants also run on nuclear power, which is another nonrenewable resource. Nuclear power plants rely on uranium, a type of metal mined from the ground and specially processed. Heat released from splitting uranium atoms is used to convert water into steam that turns turbines./35/

2.8 Security of electricity supply

As a secondary source of energy, electricity is unlike anything else in character. All digital technologies, communication infrastructure and industrial processes rely on reliable and efficient electricity systems. On the other hand, there are a number of challenges that these systems face during and after its generation. In order to avoid the systems collapse, supply and demand must match at all times. According to Marful-Sau,/32/ the production of electricity is strategic to national economies and therefore requires security in its supply to ensure growth and development. The security of electricity supply is the creation of an energy system which guarantees regular and reliable production and supply of electricity with different fuel sources to meet the national demand and reserves. When the production and supply of electricity of a country is below its national all year demand and also depends on one source to generate electricity, then that country lacks security in its electricity sector. Realizing the increase in energy consumption and demand, countries need to continuously review their energy policies to ensure long term reliability and security of energy supply. Concerted efforts must continuously be undertaken to ensure sustainability of energy resources, both renewable and non-renewable. Increasing access to cheap and new energy services must be considered first and secondly, looking for the mix of energy resources and technologies that will reduce the adverse environmental impacts and maintain sustainable development.

The concept of security supply of electricity requires diversification of sources of fuel for the generation of the electricity. The diversification of sources of supply

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ensures security since it lessens the effect of disruption from one source as alternative sources are available.

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3 GHANA'S ENERGY AND ELECTRICITY SUPPLY AND THE VARIOUS STAKEHOLDERS

3.1 The major sectors in Ghana's power supply

3.1.1 Ministry of Energy

The Ministry of Energy develops and ensures a reliable supply of high quality energy services at a minimum cost to all sectors of the Ghanaian economy. They are the highest body responsible for development of electricity policy in Ghana.

3.1.2 The Volta River Authority (VRA)

The Volta River Authority is a state-owned entity that is responsible for generation and transmission of electricity in Ghana. VRA operates the largest generation facility in Ghana, the Akosombo hydroelectric plant.

3.1.3 The Electricity company of Ghana (ECG)

The Electricity Company of Ghana is also a state-owned entity that is responsible for distribution of electricity to customers in southern Ghana, namely Ashanti, Central, Greater Accra and Volta Regions of Ghana. ECG is the entity that that consumers interact with when they receive and pay their bills or when they have service questions (bills, metering, line connection, etc.).

3.1.4 Ghana Grid Company Limited (GRIDCO)

Ghana Grid Company Limited is an independent transmission system operator formed in accordance with the Energy Commission Act, 1997 (Act 541) and the Volta Development Act, 2005 (Act, 692) by the legislation of Ghana. It operates the Interconnected Transmission System, and separates VRA's transmission activities from other activities.

3.1.5 The Northern Electrification Commission (NED)

A subsidiary of VRA the Northern Electrification Commission is responsible for power distribution in northern Ghana namely, Brong-Ahafo, Northern, Upper east and Upper west regions.

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3.1.6 The Public Utility Regulation Commission (PURC)

The Public Utility Regulatory Commission is an independent agency that calculates and sets electricity tariffs educates customers about electricity services as well as energy efficiency and conservation and ensures the effectiveness of investments.

3.1.7 The Energy Foundation

The Energy Foundation is an independent agency that licenses private and public entities that operates in the electricity sector. EC also collects and analyses energy data and contributes to the development of energy policy for Ghana.

3.1.8 The private generators

The Private Generators are domestic or international entities that build power generation facilities in Ghana. They can also be called the Independent Power Producers (IPPs).They sell their electricity to VRA or ECG. Currently there are three (3) IPPs operating in Ghana

3.1.9 Ghana National Gas Company (GNGC)

The Ghana National Gas Company was established to contribute to Ghana's rapid industrialization by providing natural gas resources and more reliable fuel imports for the power industry in a safe, cost effective, and in a responsible manner./38/

3.1.10 The Energy Foundation

A Ministry of Energy – Private Enterprises Foundation (PEF) initiative, was set up in 1997 to promote energy efficiency and conservation programmes. Initial activities focused primarily on provision of technical support to industries, introduction of compact fluorescent lamps (CFLs) countrywide and public education./24/

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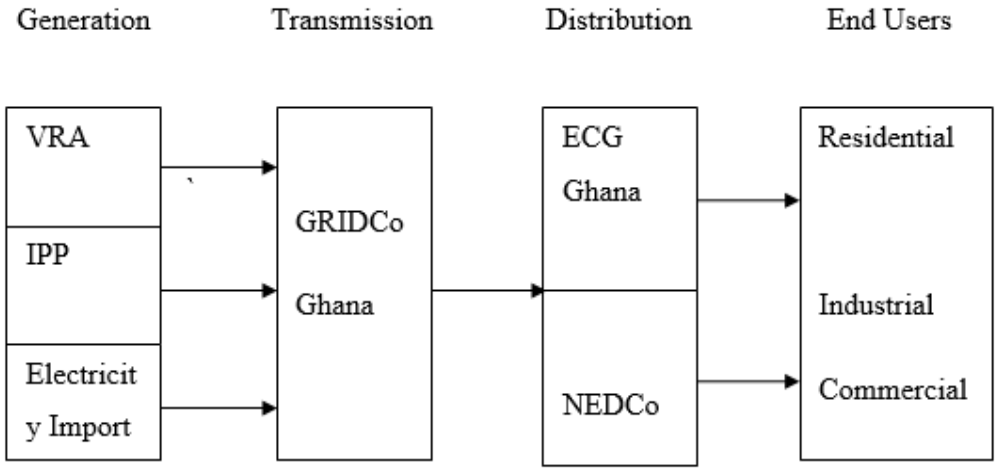

Figure 1. Structure of Ghana's electricity sector./25/

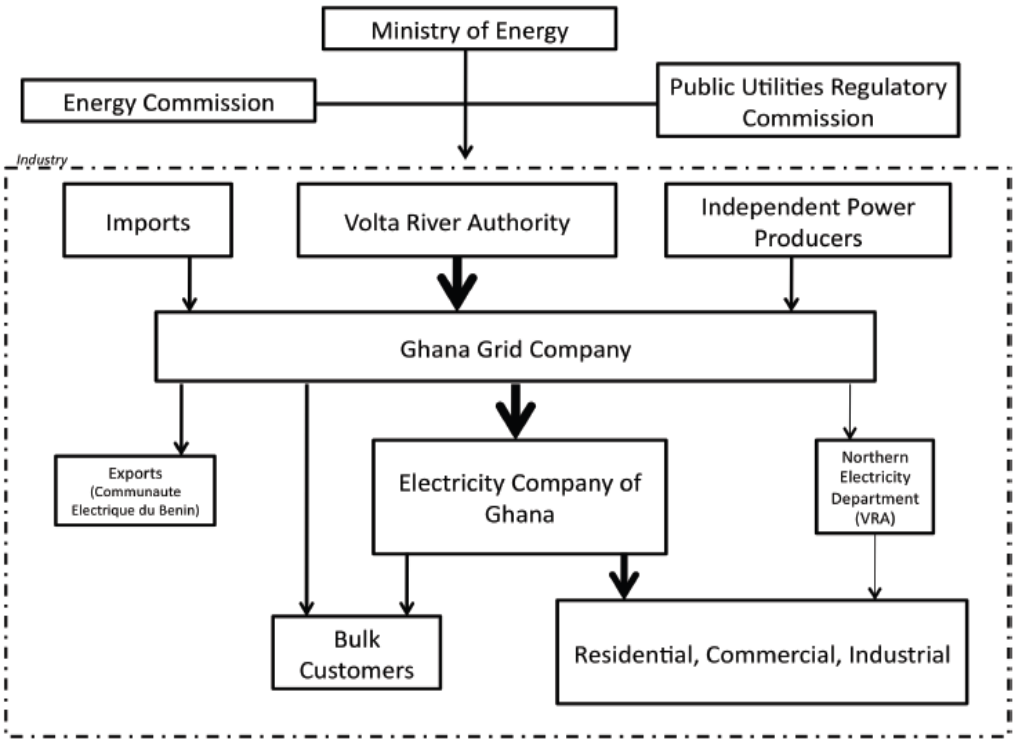

Figure 2. Structure of Ghana's energy sector./11/

3.2 Electricity in Ghana

Electricity or energy is a must necessity that any country which is willing or eager to develop must not just have, but have it in abundance since it is the backbone of a country's economy development. Electricity in Ghana is a key determinant of

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the country's continued economic growth, but supply has recently struggled to keep up with demand. Sustained demand growth of over 6 percent per year has strained the already overburdened electricity system./20/ Ghana's energy crisis has deteriorated in recent times with authorities blaming the situation on low water levels in the Akosombo Dam and lack of gas to power the country's power plants./12/ Domestic power consumers are bitterly complaining of their household appliances being destroyed, workers are also being laid-off from most industries in the country due to the persistent erratic power supply. This situation has compelled the Electricity Company of Ghana (ECG) to introduce a load shedding timetable to regulate supply of electricity to the various consumers at large. The recent erratic power supply crisis faced by the country has been projected to end in the first quarter of 2015. The country is currently shedding load between 90 to 300 MW each day due to shortfall in power generation. According to ECG, factories will lose power for forty eight (48) hours and have continuous supply for six (6) days.

3.3 Electricity power demand in Ghana

The demand of electricity in Ghana is divided across forty load centers including cities, villages, towns and both small industries and large industrial sites such as mines. Ghana's ten largest load centers accounted for almost 68% of peak demand and 72% of energy consumption in 2009./23/ Electricity consumption in the past was occasionally limited by shortage of power from the hydro plants which were the main source of power in Ghana until 1998. With additional power from thermal plants, Ghana's electricity consumption has been increasing rapidly. Since the 1990s, commercial and residential demand of electricity has been increased rapidly and has been the dominant users of electricity in Ghana. The other significant consumers of electricity have been the Volta Aluminum Company (VALCO) and the mining companies.

Over the past ten years, demand for electricity has been high in Ghana due to economic growth, urbanization and rural electrification. The growth is fuelled by expansion in information and telecommunication, business services and

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innovation in the delivery of financial services which are all dependent on energy availability. Ghana's retail electricity supply has a predominantly residential and non-residential customer base of about 70%. /7/ Ghana's offshore oil and gas exploration and production and onshore processing will further speed up this rate of growth. Ghana's electricity sector as at now has over 2 million residential and commercial customers and 1,150 industrial customers too. These customers mounted to a peak power demand of 1,423 MW and a cumulative energy demand of 10,116GWh. /23/ "The maximum amount of electricity that customers consume instantaneously is referred to as peak demand and the amount of electricity used by customers over time is also termed as energy demand" GRIDCo forecasts energy demand and peak power demand to increase by 98% and 110% respectively between 2009 and 2018./6/ The list below shows the various share of Ghana's electricity consumption

- Export/other bulk 10%
- VALCO 6%
- Mines 14%
- Residential and commercial user 70%. /45/

Table 1 Ghana's increased demand and annualized growth rates./6/

Ghana power and energy demand	**2009**	**2018**	**Annualized growth rate**
Energy demand (GWh)	10,116	19,469	7.6%
Peak power demand (MW)	1,423	2,856	8.6%

The growth rate shown above does not account for demand from Ghana's state-owned Volta Aluminum Company (VALCO), which is currently operating at only

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20% of capacity and also does not account for the developing upstream and downstream oil and gas sectors. Projected electricity occurring together in a time peak demand for the year 2014 was 2, 179.5 MW which shows an increase of 236.6 MW and a growth of 12.2% over the 2013 actual peak demand which was 1,942.9 MW. This increases also happened as a result of mines, industrial customers, residential and new loads emanating from rural projects. This is shown in table 2.

Table 2. Yearly increased in energy generated, energy consumed and peak demand./38/

YEAR	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ENERGY GENERATED (GWh)	7,273	5,882	6,039	6,788	8,430	6,978	8,324	8,958	10,117	11,200	12,024
ENERGY CONSUMED (GWh)	6,829	5,241	5,299	5,964	7,362	6,441	7,219	7,452	8,317	9,187	9,258
PEAK DEMAND (MW)	1,227	1,135	1,049	1,325	1,393	1,274	1,367	1,432	1,506	1,665	1,729

The total installed and effective capacity as at December 2013 in Ghana was 2,814 MW and 2,492 MW respectively. Out of this capacity, hydro power was about 55% of reliable capacity with the remaining capacity representing a large percentage of thermal generation whiles solar energy contributed less than a percentage (%) to the total capacity. Table 3 shows the total installed and effective generation capacity.

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Table 3. Total installed and generating capacity./38/

PLANT	INSTALLED CAPACITY (MW)	EFFECTIVE CAPACITY (MW)	TYPE	FUEL TYPE
Akosombo Hydro Plant	1,020	1001	Hydro	Water
Kpong Hydro Plant	160	120	Hydro	Water
Bui Hydro Plant	400	133	Hydro	Water
Takoradi Power Company (TAPCO) (T1)	330	330	Thermal	LCO/Gas
Takoradi International Company (TICO) (T2)	220	220	Thermal	LCO/Gas
Takoradi Thermal Plant (T3)	132	132	Thermal	LCO/Gas
Takoradi Thermal 1 Power Plant (TAPCO) (TT1PP)	110	110	Thermal	LCO/Gas
Takoradi Thermal 2 Power Plant (TAPCO) (TT2PP)	50	50	Thermal	DFO/Gas

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Mines Reserve Plant (MRP)	80	80	Thermal	DFO
Sunon Asogli	200	200	Thermal	Gas
CENIT	110	110	Thermal	LCO/Gas
Navorongo Solar Farm	2	2	renewable	Solar
TOTAL	2,814 MW	2,492 MW		

3.4 Major sources of electricity in Ghana and their problems

Supply sources used in running the various power plants in Ghana are listed below:

- Hydro
- Thermal – Gas, light Crude oil (LCO) and Distilled Fuel Oil (DFO) fired plants.
- Solar. /43/

Ghana has made tremendous strides in electricity penetration as compare to other African countries. Currently, the county enjoys a total installed capacity of 2,845 MW of electricity which is mainly from hydro, thermal and more recently from solar. Studies shows that, over 70% of Ghanaians have access to electricity on the national grid but constant supply of electricity has been a major issue for some time now. Electricity demand in Ghana is increasing at the rate of 12% which calls for urgent measures to address the situation./34/. The main source of electricity generation in Ghana is through hydro and thermal (fig.3).

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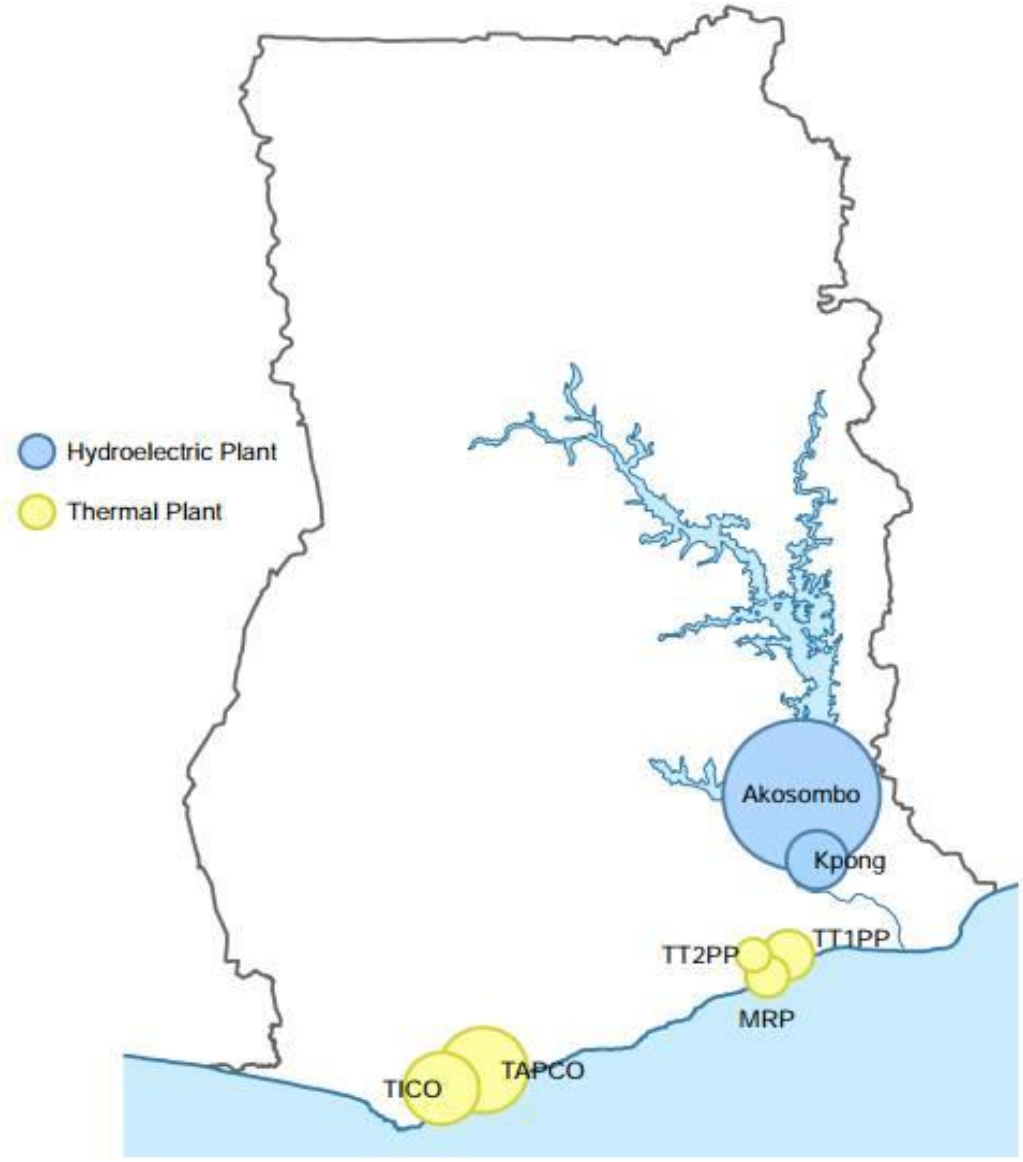

Figure 3. Map showing the location of generating resources in Ghana/23/

Below are lists of installed generating sources in Ghana

- VRA Hydro 47%
- BUI Hydro 5%
- VRA Thermal 36%
- VRA Solar 0.1%
- IPP Thermal 12%

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VRA contributes about 75% of the total generation in Ghana as at 2015. /43/

3.4.1 Ghana's hydro source of generation

Hydroelectric power is an important source of energy especially for tropical countries without advance technological development. Hydroelectric power is a preferred renewable energy source and has major advantages such as its cheap cost, zero air pollution, and long service life of plant, lower level of expertise for running and maintenance and lack of post-production storage problems. Cost per unit of electricity generated from hydro is cheaper than any other source. The Akosombo dam was established in 1966. It is a significant structure built in the Volta river basin since the resulting lake on which the dam was built is one of the largest man-made lakes in the world./9/ The construction of the Akosombo dam was managed by VRA. It was directly linked to efforts made to develop the huge Ghana's integrated bauxite to aluminum industry and, supply electricity for both industrial and domestic use and export power supply to Benin and Togo (basin sharing countries).There were three phases of the dam project. The first phase was the installation of 588 MW unit of electricity which was completed in 1966 and the second phase involved an addition of 324MW electricity which resulted in total of 912 MW at the Akosombo dam. The last phase was the construction of the smaller dam at Kpong which is 21km from Akosombo./42/

Bui dam, which is a multipurpose dam, was also built at the Bui National Park and was commissioned in December 2013. The dam as at now generates 400 MW of power and also facilitates irrigation./44/

About 75% of Ghana's hydroelectricity is generated at the Akosombo hydro power plant which motivates economic and industrial development in Ghana. Hydro dams in Ghana do not only provide electricity but provide other benefits in terms of transportation, fishing, tourism and water for irrigation activities by farmers along the banks of the Volta Lake. The country also earns foreign exchange through hydro by exporting electricity to Benin and Togo.

Hydroelectric power has been the main source of electricity in Ghana for almost half a century now. Hydroelectricity accounts for over 60% of the generation mix

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which comprises of the Akosombo Power Station, Kpong Power Station and Bui Hydro Power Station with generation capacities of 1,020 MW, 160 MW and 400 MW respectively./34/

3.4.2 Thermal plants in Ghana

There are six thermal plants in Ghana currently, two of which are located at Aboadze near Takoradi in the Western Region. These plants account for about 56% of the total thermal power capacity of Ghana./26/. These thermal plants consist of a 330 MW combined cycle power plant which is operated by VRA and another 220 MW simple cycle combustion turbine which is owned and operated by the Takoradi International Company Ltd (TICO). VRA owns 10% of TICO and the other 90% is owned by a foreign energy company known as TAQA which is Abu Dhabi's National Energy Company. This company is in agreement with the Government of Ghana and the VRA to expand their 220 MW power plant into a 330 MW power plant by adding a 110 MW steam generator turbine. These two plants can be operated on light crude oil or natural gas but are currently being mostly run on light crude oil due to challenges of natural gas availability.

The other four thermal plants are situated at one of Ghana's most industrial cities known as Team in the Greater Accra Region. These plants include a 200 MW combined cycle plant which is operated and owned by Sunon Asogli Power Company. This plant runs on natural gas which is delivered by the West African Gas Pipeline, two diesel generators that generates 49.5 MW and 80 MW respectively. The 80 MW diesel plant is operated by the Volta River Authority and owned by some mining companies. The other 49.5 MW plant is owned and operated by the Volta River Authority and there is another 110 MW simple-cycle combustion turbine which runs on light crude oil or natural gas and it is also owned and operated by the Volta River Authority.

3.4.3 Solar

VRA just completed a 2 MW photovoltaic (PV) grid connected plant which is a pilot project in Navorongo in the Northern Electricity Distribution Company (NEDCO) areas of operation.

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3.5 Ghana's electricity supply challenges

The electricity sector of Ghana has long been tied with several challenges regarding supply security and power quality. Over-dependence on hydro power in the generation mix has been one of the main factors affecting the power supply. The overall amount of energy to be supplied is limited by many factors that include low water level in the country's hydro system. Almost all of the recent power crisis (1998, 2002 and 2007) are due to low rainfall measures in the Volta basin that supply water into the Akosombo dam and a fall in the flow of water from upstream following construction of dams in Burkina Faso on an important water source to the Volta lake.

Transmission systems in Ghana, mainly those in the Southern part of Ghana are very old. They were built mainly in the 1970s with very little subsequent investment. Almost half of Ghana's 161 KV transmission infrastructures are long past their recommended retirement age. In the year 2012, ECG and NEDCO were experiencing 20% distribution losses which were quite high by industry standards. The operation of these utilities is critical in ensuring that the cost of supply is minimized as well as maintaining the financial sustainability of the sector.

Studies conducted by the World Bank /45/, show that VRA's thermal power stations at Takoradi and Tema are not functioning properly. These weaknesses have worsened the recent period of load shedding since September 2012 as these units were unable to operate at full capacity on a sustained basis to mitigate the loss of output from the Sunon Asogli due to gas supply cut-off.

Apart from the low water levels fed into the various dams in Ghana, there are other problems constraining the country's electricity supply, such problems are also due to the factors listed next

3.5.1 Challenges on the supply side

- Inadequacy of available generation capacities to meet the projected demand under all system conditions.

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The reserve margin in 2009 was about 9.7% and has been wiped out between 2005 and 2006 as a result of operating VALCO. In 2008, it was increased from 5.9% to about 10% in 2011/2012 and has recently been wiped out again as a result of the fall in the West African Gas Pipeline./1/ Generating capacity reserve that allows the system to tide over any generating outages, errors in the demand forecasting and any other fault or unplanned outages are inadequate

Ghana's peak load ranges between 1,900 to 2,200 MW in 2014 and the total peak on the grid transmission system would lie within 2,200 to 2,300 MW. Projected electricity demand within the constraints of limited available supply means that there is bound to be significant supply shortfalls any time a power plant is turned off even for scheduled maintenance./18/

- Poor planning and untimely schedule of maintenance and retrofit upgrades to the power plants, transmission and the Distribution Lines.

Studies /24/, show that most of the power plants in Ghana are not providing their supposed power output mainly because they are not functioning properly. This is due to poor maintenance of equipment installed over many years ago and overloads in the low voltage systems has resulted in a shortfall on electricity services delivery to customers. Currently, the losses in the transmission and distribution system are estimated to be 25% whiles wastage in the end-user is also estimated at 30%. /25/

The distribution network of ECG at the end of 2010, consisted of 26 bulk point of supply, and distributed a total of 6,771.3 GWh of electricity of which 26.9 % was counted as losses, compared to 3,989 GWh in 2000, with 27% losses which are both commercial and technical.

On the other hand, NEDCO also consist of 5 bulk supply point and distributed 635 GWh of electricity of which 25.55 was accounted for as losses, as compared to 330 GWh in 2000 with 30% losses also being both commercial and technical (fig.4)./26/

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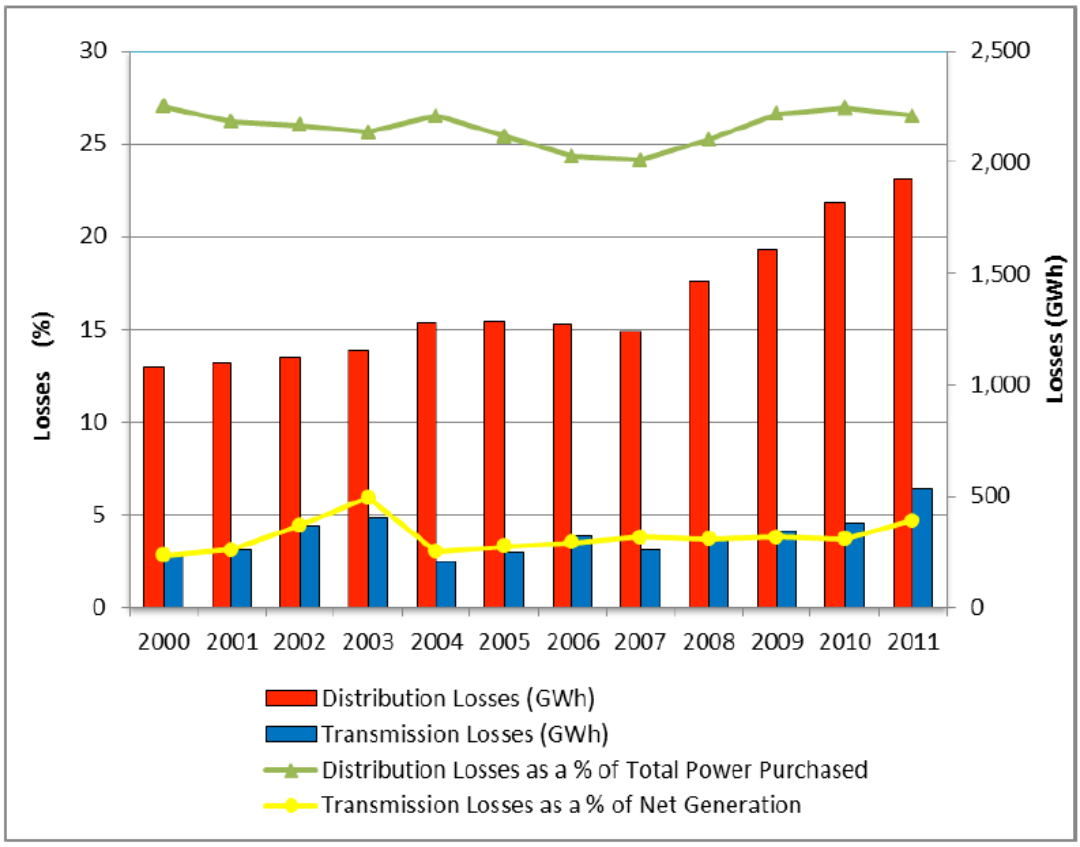

Figure 4. Electricity transmission and distribution losses in Ghana 2000-2011

- Gas supply uncertainties

Another challenge limiting the supply of electricity is the poor supply of natural gas to power the generating plants due to inability of the West African Gas Pipieline project to feed the country from Nigeria. The West African Gas Pipeline is a regional distributing network project delivering gas from Nigeria to nearby countries including Benin, Togo and Ghana but unfortunately the project has not been able to provide the supply of gas. Apart from the vulnerabilities to gas supply, VRA is faced with risk emanating from unfavorable oil price and exchange rate movements. All these have been factors endangering the performance of the power supply sector./45/

- Pricing/tariff and subsidy policies

The price paid by electricity consumers has been lesser than the cost of supply. Persistence of low tariffs has resulted the state's electricity providers into a dan-

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gerous financial situation causing their inability to maintain and expand the system's physical structure adequately, leading to poor quality of supply while at the same time the burden of these subsidies weighs heavily on the nation's budgets. These have led to serious deterioration in the operations of power supply over past several years. Low tariffs have also made the electricity sector unattractive to private investors. Huge amounts of money are being spent by the government to subsidies energy consumption because of tariffs being persistently below cost.

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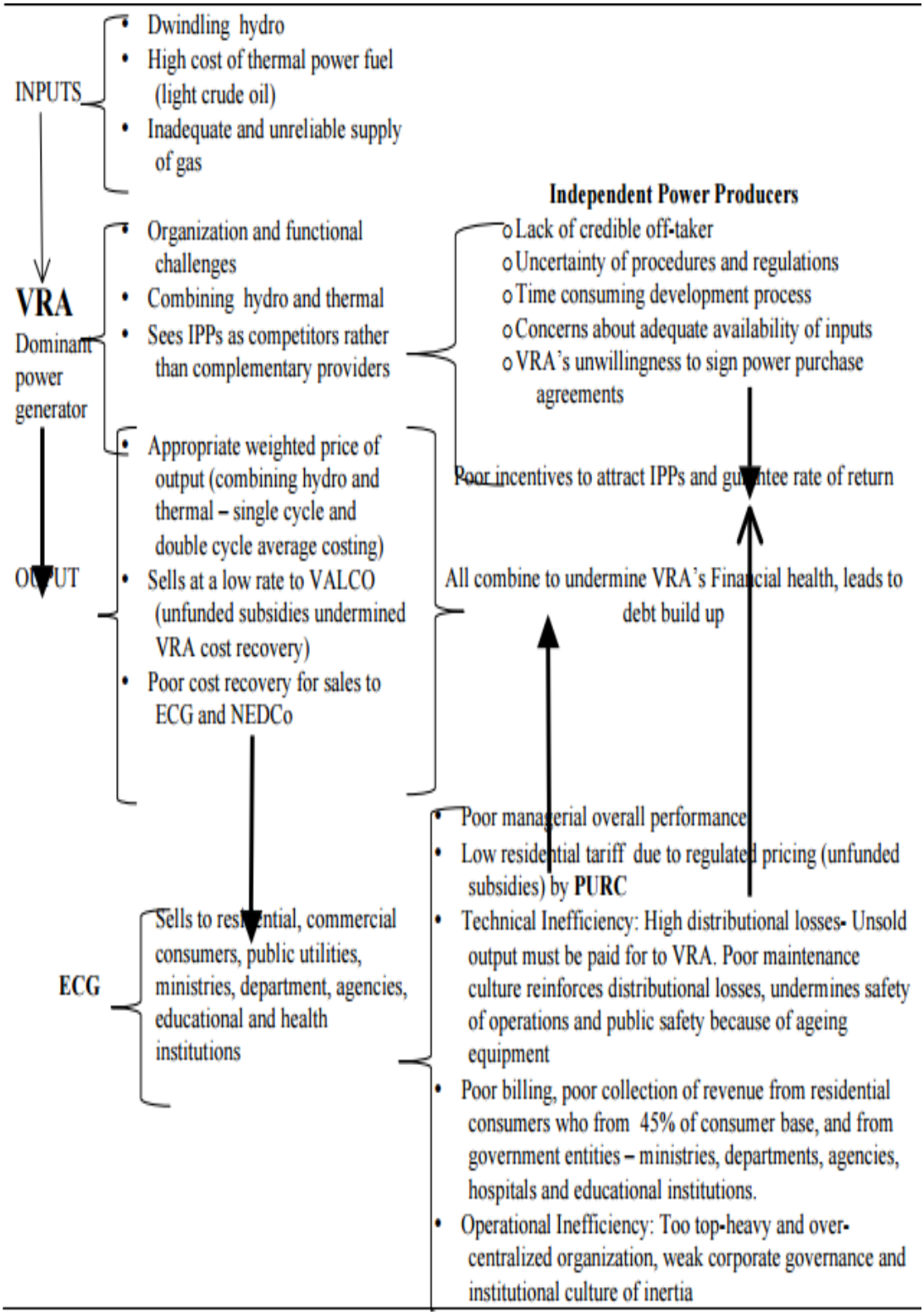

Figure 5. Supply side challenges./24/

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3.5.2 Challenges on the demand side

Illegal connections, problems related to metering, billing and collection bills has also been major challenges working against the capacity revenue whiles growing demographic needs in health delivery and technology in everyday activities from the home to the office which are seen to be population growth and increased standard of living have also been another factor. In addition, the predominant residential and non-residential customer base of the power industry, as high energy sensitive production activities (manufacturing and mining) decrease, makes economic pricing, strong billing and collection system critical to the financial viability of the industry. Most of government institutions consume much of electricity and are highly indebted to the distribution sector, especially ECG which is also resulting in cash flow difficulties for the company.

The World Bank power sector reports in 2005 and 2009 made recommendations that underlie these challenges and these recommendations are still valid as they were ten (10) years back, giving the impression that the power sector would have been better than it is now if efforts were gradually made to rectify these challenges. Below are the findings made by the World Bank report in 2005 and 2009.

3.5.3 World Bank Report Findings in 2005

The lists below are the finding made by the World Bank report in the year 2005.

- Enhancing efficiency in all aspects of the sector is the key challenge before Ghana's policy makers.
- The sector institutions are caught in a downward spiral of below-potential performance, low resource mobilization and underinvestment, and mounting arrears of payment between sector entities and government entities.
- Timely implementation of power sector reforms is critical.
- Measures to promote efficient use of assets are vital.
- Efficiency issues are most pressing in the distribution sector.
- VALCo subsidies should be transparent and must be funded by government.

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3.5.4 World Bank Report Findings in 2009

The lists below are another finding made by the World Bank in the year 2009.

- VALCo is negatively impacting the financial viability of the sector.
- Much of the country's high-voltage transmission system is aging badly and increasingly unreliable. The risk of outages is significant and will continue to rise.
- The electricity distribution subsector suffers from poor commercial and operational performance. High losses are due to overloaded networks, combined with problems of metering, billing, theft and inadequate revenue collection.
- Weak management and regulation of the electricity sector by the government remains a key issue./7/

3.6 Industries affected most by power outage in Ghana

The functioning of businesses are inconceivable in the absence of electrical power, even a brief outage can cause tremendous losses of productivity, material, revenues and even loss of lives. Power failure to individual company varies by industry and the nature of application. It can range from being disruptive to live threatening. Below are industries and business function that are severely affected by power failure:

3.6.1 Manufacturing Industries

There is loss of material, loss of productive time and breakdown of machinery as power failure brings production lines to sudden stop. This also causes supply chain to shut down altogether.

3.6.2 Financial Corporations

In industries where millions of dollars can be made in a fraction of a second, power failure renders financial corporations unable to carry out crucial transactions on time. This is the same as with millions on unrecoverable dollars per minute of downtime followed by several additional hours of recovery time.

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3.6.3 Consulting and Information Technology (IT) Services

IT operations are an organization's window to the rest of the world, power failure result in crushed computer systems, losses of data and sudden termination of communication with client. This is often followed by several weeks of effort spent in creating hundreds of man-hours of work. Programs and data may get corrupted resulting in software recovery operations that may not be resolved.

3.6.4 Data centers

Data centers form backbone of operations for several organizations such as financial service firms, insurance companies, and IT firms among others. Power failure here can cause an irrecoverable loss of thousands of records stored over the years and disrupt ongoing transactions too.

3.6.5 Control Centers

Traffic signal operation, public transport system like the railways, control centers for air traffic management, telecommunications and utilities all rely heavily on continuous power supply for smooth operations. Disrupt in such critical operations can jeopardize the safety and security of millions of unsuspecting consumers in an instant.

3.6.6 Perishable Items

Pharmaceutical industries, petrochemical industries and food processing plants rely heavily on uninterrupted availability of power supply for storage and preservation of perishables that have extremely limited life span. Power outage can cause in-process products worth several millions of dollars to be discharged due to damage, spoilage or contamination.

3.6.7 Medical Facilities

In hospitals, patients' lives are delicately supported by health monitoring systems. Any discontinuity in the normal functioning of medical equipment can directly translate into loss of lives.

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3.6.8 Military Operations

Power failure render valuable equipment, weaponry and even personnel, defenseless and hence, exposing them to the risk of attack.

3.6.9 Entertainment Venues

Cancellation of money-spinning events for brief periods of time equates to huge losses of revenue for entertainment facilities. It also result in sudden termination of routine operations which can become hazardous to visitors and operating personnel as well.

3.6.10 Safety and Security

Power outages can endanger the safety of the common man. People can be trapped in or out of buildings with automated access control systems, elevators can come to a sudden stop and are plunged into darkness, fire alarms and water sprinkles may cease to function, communication via phone or email with emergency services could be inhibited. These are just a few examples of power outages becoming more than just a nuisance factor and threatening to endanger the safety and lives of millions of people simultaneously./13/

3.7 Impact of frequent power outage on industries in Ghana

The cost of wholesale power reliability failure is enormous and can have a deleterious effect on Ghana's economy/23/. This shows that, electricity is an important ingredient in a county's economic development which in the other way, shows the measure of standard and the quality of life of people. The economic progress and social development of a country is hardly achieved when there is no safe, sustained, reliable and affordable supply of electricity that meets the county's demand. Major factors that drive growth in the power sector are economic expansion, population growth and the general economic performance of the country. The direct effect of electricity comes into play when households are added or businesses and industries expand and the indirect effects also comes from the contribution that electricity makes to people's way of living, quality of life and development in technology. The drivers of Ghana's economic growth are the service sectors, which constitutes 50.2% of the economy, followed by the industries

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which are also at 28.4% and agriculture 19.9%. /2/ The Ghana Statistical Service (GSS) issued a provisional gross domestic product (GDP) figures that suggest that, the Ghanaian economy expanded by 4.2% in 2014 which is less than the growth of 7.3 recorded in 2013. Ghana has had to halve its economic growth forecast for 2015 partly due to the chronic power outages that are hurting investors' confidence in the economy.

The electricity supply industry is a key driver of economic growth and development which powers the country's industrial, urban and commercial development. The unreliable power supply in Ghana has affected both the major and minor businesses. Businesses such as mechanics, hairdressers, cold store operators, small scale manufacturers and traders depend on reliable power supply to run their businesses profitably but due to the unreliable supply of power, there have been lots of job cuts, lower cooperate taxes, reduced foreign exchange receipts and considerably lower contribution of the sector to the country's gross domestic product./28/

There is high cost of living since inflation is always on the rise. This is because the cost of doing business is high, especially in the telecom industry, manufacturing and production industries since producers in Ghana use generators which operate on diesel/petrol or any other sources of power supply. The additional costs of production are then shifted to consumers. There have been high unemployment rate since there is no frequent supply of power to boost the growth of existing businesses and the establishment of new firms. Most private businesses which are mostly the major drivers of the country's economy are also affected negatively by the erratic supply of electricity. The Ghanaian currency (Cedi) also keeps depreciating against other trading currencies due to reductions in local productions which creates avenue for traders to import goods and services from other countries.

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4 RENEWABLE ENERGT POTENTIALS IN GHANA

This chapter gives a review of assessed renewable (RE) resources in Ghana with the target of finding their potentials to improve the current erratic supply of electricity situation in the country.

Figure 6 shows energy resources in Ghana and was created by Hon. Emmanuel Armah Kofi Buah (Minister for Energy and Petroleum, Ghana, 2014) and presented by Wisdom Ahiataku-Togobo, Director, Renewable Energy-Ghana.

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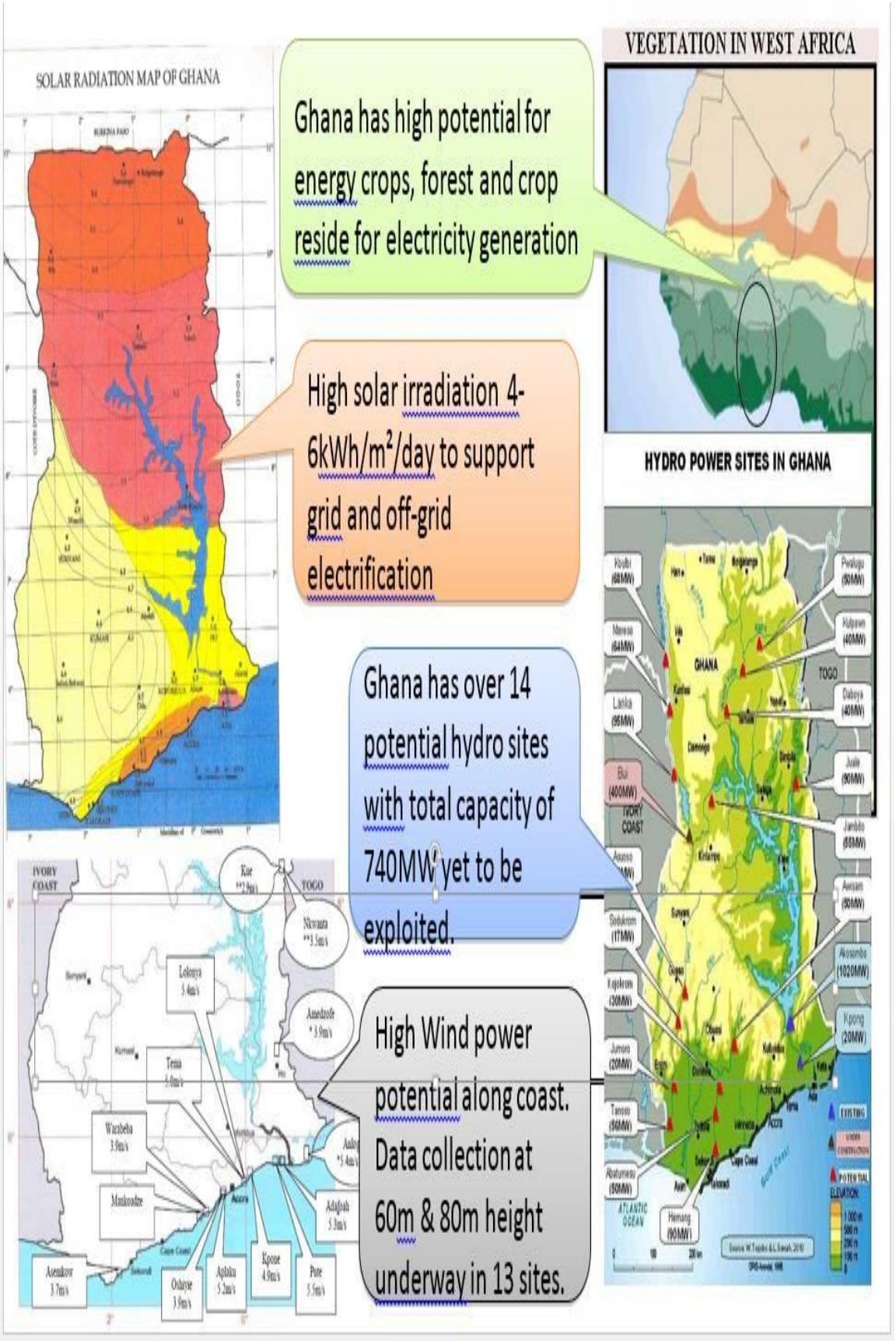

Figure 6. Energy resources in Ghana

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Table 4. Energy Resources in Ghana detailed with figures.

Resources	Value	Units	Rank	Period	Sources
Wind Potential	1,124	Area(km2) Class 3-7 Wind at 50m	59	1990	NREL
Solar Potential	706,055,035	MWh/year	73	2008	NREL
Coal Reserves	Unavailable	Million Short Tons	N/A	2008	EIA
Natural Gas Reserves	22,650,000,000	Cubic Meters (cu m)	76	2010	CIA World Factbook
Oil Reserves	15,000,000	Barrels(bbl)	87	2010	CIA World Factbook

The Government of Ghana has set a target of ensuring that renewable energy sources account for 10% of the country's energy mix by the year 2020 /32/. To reach the aim, the Government of Ghana passed the renewable energy Act, 2011 (Act 832) (the "Act") providing the legal and regulatory framework necessary for enabling and expanding the country's renewable energy sector. The Act aims to promote, develop, manage, utilize, sustain and ensure adequate supply of renewable energy resources for power, heat and other related purposes.

Policies supporting the RE resources in Ghana exploitation are listed below:

- Feed-in-tariffs scheme which is made of feed-in-tariff rates
- Mandatory purchase of electricity generated from renewable energy sources
- Free access to the distribution and transmission systems
- Creation of the Renewable Energy Fund dedicated to the promotion development of the renewable energy sub-sector in Ghana.

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- Net metering – (distributed generation) under which renewable energy generated on site may be delivered to the local utility to offset the cost of electricity provided by the utility.

4.1 Solar energy

Reports presented by the World Bank in 2013 shows that there is abundant solar resources in Ghana. The monthly average solar irradiation is estimated to be between 4.4 and 5.6 KWh/m2/day with sunshine duration of between 1,800 and 3,000 hours per annum. The potential for using solar to generate electricity is very high with consideration that many parts of the country receive 5-8 hours of sunshine per day at 1 KW/m2 (fig.7).

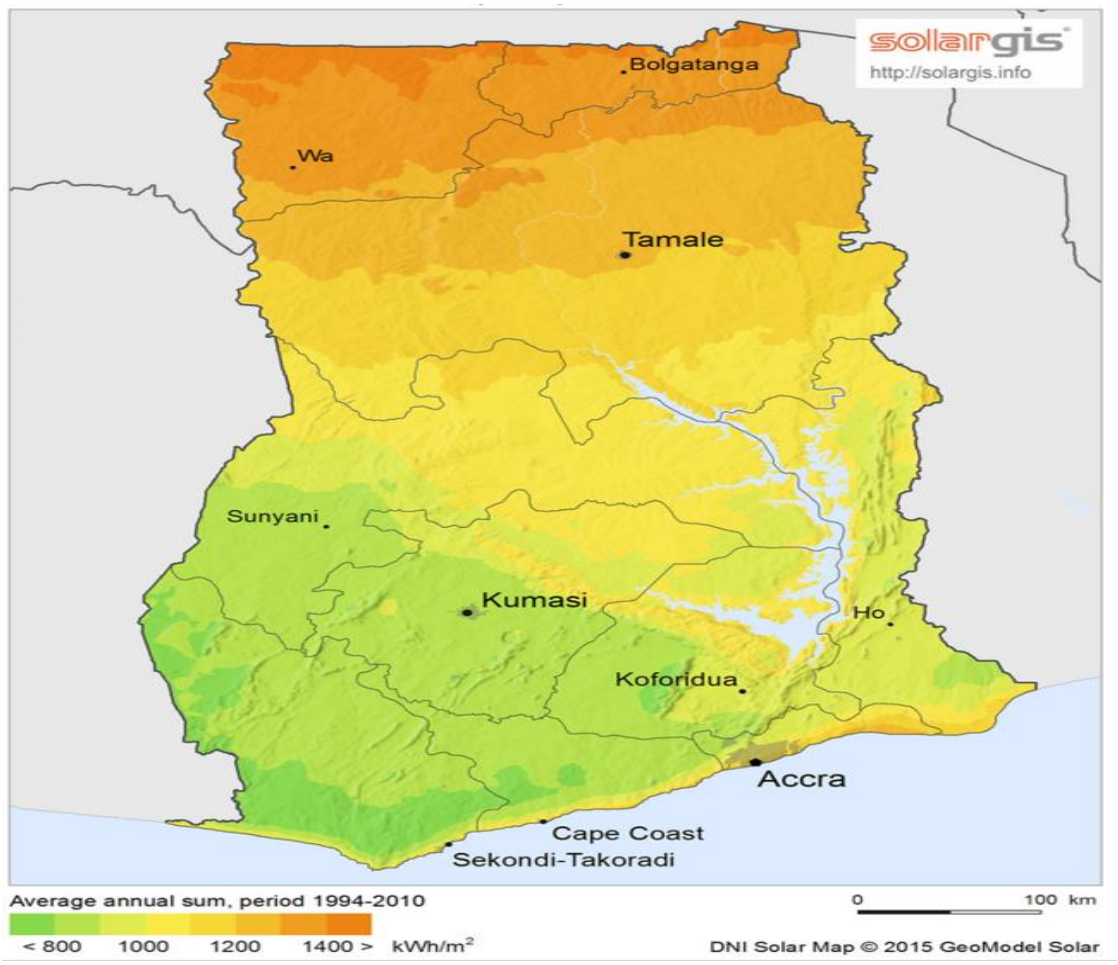

Figure 7. Direct Normal Irradiation Map of Ghana

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Among the solar irradiation levels shown on the map, the areas with the highest irradiation are spread across the entire northern belt of Ghana whiles the lowest amount of solar radiation happens to be in the eastern part of Ghana.

United Nations Environment Program (UNEP) study known as SWERA (Solar and Wind Energy Assessment, conducted from 2002 to 2005 by a US institution known as NREL (National Renewable Energy Lab) in conjunction with Ghana Energy commission and Meteorological Service Department (MSD) came out with results that shows the magnitude of solar irradiation within the various study areas (towns and cities) and monthly averages of solar irradiation in Ghana. The table 5 and 6 show the summary of the comparison of the results.

Table 5. Year Monthly Averages of Solar Irradiation (kWh/m2 -day) at 9 Synoptic Stations./39/

MONTH	KUMASI	ACCRA	AXIM	NAV'GO	HO	ADA	K'DUA	WENCHI	TAMALE
JAN	4.818	4.660	4.882	5.391	4.872	4.995	4.711	5.193	5.124
FEB	5.313	5.206	5.399	5.400	5.224	5.381	5.139	5.495	5.479
MAR	5.305	5.256	5.569	5.783	5.509	5.649	5.260	5.483	5.613
APR	5.356	5.665	5.605	5.958	5.716	5.937	5.434	5.711	5.890
MAY	4.709	5.416	5.051	5.934	5.576	5.570	5.287	5.507	5.869
JUN	4.029	4.613	3.936	5.719	4.916	4.978	4.641	4.972	5.510
JUL	4.036	4.189	4.242	5.339	4.601	5.064	4.074	4.356	4.954
AUG	3.783	4.527	4.230	5.098	4.187	5.065	3.842	4.120	4.841
SEP	3.992	5.107	4.382	5.324	4.663	5.510	4.437	4.405	5.004
OCT	4.707	5.623	5.178	5.677	5.500	5.872	5.174	4.927	5.472
NOV	5.000	5.510	5.466	5.616	5.624	5.480	5.241	5.127	5.695
DEC	4.552	4.930	4.986	4.824	5.074	5.359	4.857	4.905	5.213
Av'ge	4.633	5.059	4.911	5.505	5.122	5.409	4.841	5.017	5.389

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The table below shows summary of comparison results (solar irradiation in kWh/m2 -day) taken both by satellite and ground level in some selected cities and towns in Ghana.

Table 6. Summary of results showing solar irradiation comparison in KWh/m^2 – day. /39/

Synoptic Station	Ground (kWh/m^2-day)	Satellite (kWh/m^2-day)	% Error
Kumasi	4.633	5.155	-11.3
Accra	5.060	5.180	-2.3
Navrongo	5.505	5.765	-4.7
Abetifi	5.150	5.192	-0.8
Akuse	4.814	5.58	-15.9
Wa	5.520	5.729	-3.7
Akim Oda	4.567	5.177	-13.3
Wenchi	5.020	5.093	-1.5
Ho	5.122	5.223	-2.0
Kete Krachi	5.280	5.345	-1.3
Takoradi	5.011	5.200	-3.8
Yendi	5.370	5.632	-4.8
Bole	5.323	5.570	-4.6

In spite of this high solar potential, little of it has only been done to exploit this resource for grid connected power generation.

4.1.1 Barriers to solar energy usage in Ghana

- Lack of education on solar PV which is due to over dependency on the national grid
- High cost of components
- Lack of finance for service providers and installers

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- Unresponsive attitudes of potential market groups in Ghana (e.g. The real estate industries)
- Lack of finance for consumers
- Perception of high cost of PV by the public
- Government of Ghana's expenditure on the national grid over the years has been more or less considerable as compared to PV, grid extension to rural areas and this has turn out to be a one of the prime factors of low spread of PV in the country as compared to other developing countries./8/

4.2 Ghana's Wind Energy Potentials

Ghana's best wind resources are primarily found along the stretches of its eastern coastline. It has a marginal wind speed of mostly 6-7 meters per second (m/s) at 50m. The SWERA studies results also concluded that, of the 6 wind classes, (with class 6 being the highest wind resource potential and class 1 being the lowest), Ghana has 4-6 wind resources at the highest ridges near the border with Togo and the highest ridges northwest of Accra with an approximate 413 km sq. area with good-to-excellent (class 4-6) wind resource which could be used to generate over 2,000 MW of wind power and if moderate-to-excellent wind resources are included, at about 5,640 MW could be generated.

The SWERA studies further revealed that, the maximum energy that could be tapped from the country's available wind resource for electricity is estimated to be about 500 – 600 GWh/year (fig.8)

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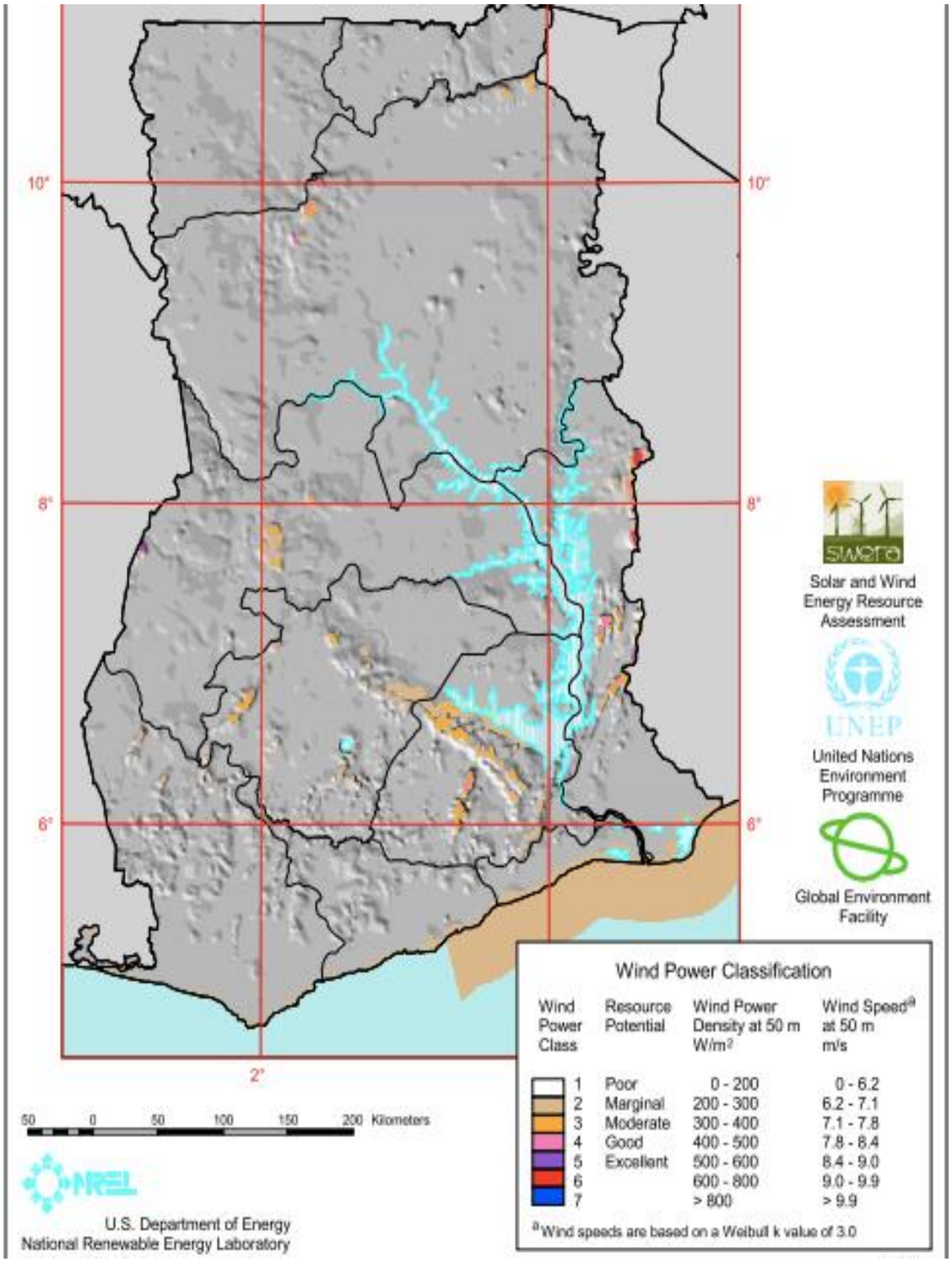

Figure 8. Ghana's wind map /39/

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The tables below show details of Ghana's wind resource potentials

Table 7. Ghana's wind resource potentials /22/

Good-to-Excellent Wind Resource at 50 m

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Good	4	400 – 500	7.0 – 7.5	268	0.1	1,340
Excellent	5	500 – 600	7.5 – 8.0	82	<0.1	410
Excellent	6	600 – 800	8.0 – 8.8	63	<0.1	315
Total				413	0.2	2,065

Moderate-to-Excellent Wind Resource at 50 m

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Moderate	3	300 – 400	6.4 – 7.0	715	0.3	3,575
Good	4	400 – 500	7.0 – 7.5	268	0.1	1,340
Excellent	5	500 – 600	7.5 – 8.0	82	<0.1	410
Excellent	6	600 – 800	8.0 – 8.8	63	<0.1	315
Total				1,128	0.5	5,640

*Wind speeds are based on a Weibull k value of 2.0

Assumptions
Installed capacity per km^2 = 5 MW
Total land area of Ghana = 230,940 km^2

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4.2.1 Barriers to renewable energy in Ghana

There is considerable RE potential to address both grid and off-grid needs of the region./16/. In the context of ECOWAS, Ghana's renewable energy potential is among the best in the sub-region. Ghana has 11.5% of the total 1411 MW medium to large scale identified renewable energy projects in the ECOWAS sub-region. Ghana has the highest and the second highest concentrated solar power potential (40 MW) and wind potential (100 MW) respectively among the ECOWAS sub/region. Out of these renewable energy potential endowed on Ghana, very little have been exploited to generate electricity due to the following:

- Cost per kilowatt hour

High cost per unit to consumers as compared to energy from other sources (e.g., fossil fuel). This has been one of the critical challenges to the adoption of renewable energy in Ghana.

Feed-in-tariff for utility scale renewable energy inter-connected in Ghana as in 2014. Index was at exchange rate of GHs3.1986/US$ in September 30, 2014.

- ❖ Hydro < 10 MW: GHp53.62/KWh (US$c16.76)
- ❖ Hydro > 10 MW: GHp53.88/KWh (US$c16.85)
- ❖ Biomass: GHp56.01/KWh (US$c17.51)
- ❖ Waste-to-energy: GHp59.03/KWh (US$c18.46)
- ❖ Biomass (plantation as feedstock): GHp63.29KW/h (US$c19.79)
- ❖ Wind (without grid stability system): GHp51.43KW/h (US$c16.01)
- ❖ Wind (with grid stability): GHp53.74KW/h (US$c17.42)
- ❖ Solar (without grid stability/storage system): GHp58.36KW/h (US$c18.25)
- ❖ Solar (with grid stability/storage system): GHp58.36KW/h (US$c20.01)

The list above only shows feed-in-tariff for different energy sources in 2014.

- High initial cost to start up

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- Uncoordinated research and development
- Lack of awareness of funding opportunities to support renewable energy technology development and promotion.
- No favorable regulatory and fiscal regime to attract investors (lack of favorable policy and financing schemes)./3/
- Compatibility with existing transmission and distribution networks.
- Low information and education as well as lack of skilled workforce and technical knowhow with the renewable energy technology.

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5 CONCLUSIONS AND RECOMMENDATIONS

Below are the findings from this study and the recommendations made as solutions to end or minimize the electricity supply challenges in Ghana.

5.1 Research Question 1: What are the main causes of the insufficient energy production in Ghana?

- Inadequacy of available generating capacities to meet the projected demand under all system conditions.
- Poor planning and untimely schedule of maintenance and retrofit upgrades to the power plants, transmission and the Distribution Lines.
- Gas Supply Uncertainties
- Pricing/tariff and subsidy policies

Recommendation:

- There should be initiatives to be taken by the Ghanaian Government in order to move the power sector ahead on development. These initiatives should include making solid decisions that focuses on ensuring the financial viability of the power sector. Thus:
  - ✓ Electricity tariffs should reflect the true cost of electricity and the cost must be transparent.
  - ✓ Officials should also chase least cost options in investments too.
- There should be a restructuring of Ghana's interconnected radial electricity generating station grid system and a proper maintenance, carried out at regular basis to avoid untimely breakdown of the power transmission and distribution equipment.
- The government should create an equal ground for both independent power producers (IPPs) and other investors by ensuring efficient pricing for electricity so that the price for electricity will not be lesser than the average production cost in order to encourage the participation of private and international investors. This will further de-monopolize the power sector and bring competition in the supply and production of electric power.

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- There should be a consumer friendly billing system developed by the appropriate agencies and the rules and regulations surrounding the procurement of getting electricity meters should be dropped lesser to encourage consumers to pay and have their meters within a reasonable period of time.
- There should be a prioritize efforts demonstrated by the government by making long term plans that focus on the capabilities and regulations needed for the sector to prosper but not just focus on the plants and associated infrastructure.
- Ghana should practice the habit of adopting energy mix by exploiting Ghana's renewable energy potentials (especially, wind, solar and biomass)

5.2 Research Question 3: What other energy resources can be used to improve electricity supply in Ghana?

This study earlier on again showed that Ghana has high amount of renewable energy potentials (solar, wind and others that were not talked about in this study) that could be used to generate electricity to compensate the increase demand of electricity in the country but the challenges listed below have been the bottleneck restraining their exploit to generate enough electricity

- High cost per unit to consumers as compared to energy from other sources (e.g. fossil fuel). This has been one of the critical challenges to the adoption of renewable energy in Ghana.
- High initial cost to start up
- Uncoordinated research and development
- Lack of awareness of funding opportunities to support renewable energy technology development and promotion.
- No favorable regulatory and fiscal regime to attract investors (lack of favorable policy and financing schemes)
- Compatibility with existing transmission and distribution networks.
- Low information and education as well as lack of skilled workforce and technical knowhow with the renewable energy technology.

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Recommendations:

- There should be lots of training programs, workshops, education and campaigns to create awareness.
- The renewable energy technologies should be used and practiced at locations where these resources or energy potentials are found. These can also help in championing the rural electrification project in the country.
- Most of the government institutions such as schools, hospitals, etc. buildings should be integrated with these technologies, especially solar photovoltaic (PV) to produce electricity in order to raise public awareness and education.
- The government should make necessary flexible financial structures such as loans, grants and other incentives available to support individual entities, private organizations and providers of renewable energy technologies.
- The government must also give clear backing and meaningful policies with good regulatory frameworks that encourage the private sector to invest in renewable energy technologies for power delivery.

CONCLUSION

Even though Ghana has lots of renewable energy potentials such as wind, solar and other resources that can be used to generate reliable, sustainable and sufficient electric power to serve the country, erratic and insufficient power supply has rather been a major challenge tormenting the country's power sector and the country as a whole. The first of the insufficient power supply challenge was in 1983 to 1985 and was due to low water level in the Akosombo dam. The recent power challenge begun in 2012 and at the time of this research, the challenge that begun in 2012 is still not been solved yet. Gas supply uncertainties, improper functioning of some power plants, poor maintenance of transmission and distribution lines, lack of energy mix, poor pricing and tariffs, and other reasons have been the major causes of Ghana's recent erratic and insufficient power supply. The effect of

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this is increased energy demand as Ghana's population, industries and people standards of life are rising.

This study has made clear the challenges facing Ghana's power generation sector and barriers such as high initial cost to startup, lack of awareness of funding opportunities to support renewable energy technology development and promotion that are underpinning the utilization of the high potential of renewable energy resources endowed upon Ghana to generate electricity to compensate for the increased demand of electricity in the country. Therefore, through recommendations made in this study, solutions are put forward to end or minimize the electricity supply challenges in Ghana and hope these solutions are considered by the power sector and the Government of Ghana.

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REFERENCES

1. African Center for Energy Policy, 2015. The Main Challenges Facing The Power Sector In Ghana. Accessed 22.11.15 http://www.aceplive.com/the-main-challenges-facing-the-power-sector-in-ghana/
2. African Economic Outlook; Ghana 2014. Accessed 1.12.15 http://www.africaneconomicoutlook.org/fileadmin/uploads/aeo/2014/PDF/CN_Long_EN/Ghana_ENG.pdf
3. Ahiataku W., Progress made by Ghana on RE Project Implementation and lessons learned for AREA. http://www.worldfuturecouncil.org/fileadmin/user_upload/PDF/PkfA-W._Ahiataku-Togobo GH_Ministry_of_Energy_Progress_made_by_Ghana_on_RE_Project_Implementation.pdf
4. Alawiye A. B. 2011. The power sector and industrial development in Nigeria. Accessed 4.11.15 https://www.theseus.fi/bitstream/handle/10024/37421/Alawiye_Abideen.pdf?sequence=2
5. Amartya Sen. 1983. Development: Which Way Now? Economic Journal, Vol. 93 Issue 372. Pp.745 a
6. Amendi Energy, 2013. GHANA'S ENERGY MARKET. Accessed 12.11.15 http://www.amandi-energy.com/pages/energy_market
7. Amoako J.T and Asamoah J., 20 15 "Thinking Big" and Reforming Ghana's Energy Sector. Accessed 27.11.15 http://includeplatform.net/wp-content/uploads/2015/03/GTF-Energy-in-Ghana-SR-formatted.compressed.pdf
8. Attachia J.C. and Amuzuvi C. k., 2013. Renewable Energy Technologies in Ghana: Opportunities and Threats. Accessed 7.12.15 http://maxwellsci.com/print/rjaset/v6-776-782.pdf
9. Barry B., Obuobi E., Andreini M., Andah W. and Pluquet M., 2005). The Volta River Basin, Comprehensive Assessment of Water Management in Agriculture. Accessed 14.11.15

`

http://www.iwmi.cgiar.org/assessment/files_new/research_projects/River_Basin_Development_and_Management/VoltaRiverBasin_Boubacar.pdf

10. Bednyagin D, 2010. Socio-Economic Assessment of Fusion Energy Research, Development, Demonstration and Deployment Programme. Accessed 22.10.15 http://infoscience.epfl.ch/record/148599/files/EPFL_TH4732.pdf
11. Country Nuclear Power Profiles. Accessed 12.11.15. https://www.google.fi/search?q=structure+of+power+sector+in+ghana&rlz=1C1VFKB_enFI623FI624&espv=2&biw=1280&bih=923&source=lnms&tbm=isch&sa=X&ved=0CAYQ_AUoAWoVChMI7rna1InhyAIVBM9yCh0Q-wPN#imgrc=AvvUFNeSc_NzjM%3A
12. Dasmani L, 2014. "Ghana's power crisis deepens" The African Report. Accessed 16.11.15 http://www.theafricareport.com/West-Africa/electricity-ghanas-power-crisis-deepens.html
13. Diesel service and supply, 2013. Accessed 30.11.15 http://www.dieselserviceandsupply.com/Industry_Power_Outages.aspx
14. *Doe F, Asamoah E. S.* 2014. The Effect of Electric Power Fluctuations on the Profitability and Competitiveness of SMEs: A Study of SMEs within the Accra Business District of Ghana. Accessed 29.10.15. http://www.cjournal.cz/files/174.pdf
15. Douglas F. B., William M. F., 1996. RURAL ENERGY IN DEVELOPING COUNTRIES: A Challenge for Economic Development. Accessed 27.10.15 http://www.annualreviews.org/doi/abs/10.1146/annurev.energy.21.1.497
16. ECOWAS Renewable Energy Policy, 2012. Accessed 8.12.15 http://www.ecreee.org/sites/default/files/documents/basic_page/151012_ecowas_renewable_energy_policy_final.pdf
17. Electricity Generating Sources. Accessed 5.11.15 http://www.electricalfacts.com/Neca/science/electricity/sources.shtml
18. ENERGY COMMISSION, GHANA. 2014 ENERGY (SUPPLY AND DEMAND) OUTLOOK FOR GHANA. Accessed 24.11.15

`

https://s3.amazonaws.com/ndpc-static/pubication/2014+Energy+Outlook+for+Ghana.pdf

19. Energy for Economic Growth, Energy Vision Update, 2012. Accessed 1.11.15 http://reports.weforum.org/energy-for-economic-growth-energy-vision-update-2012/
20. Energypedia, 2014. Accessed 16.11.15 https://energypedia.info/wiki/Ghana_Energy_Situation#_ftnref1
21. Essays, UK. (November 2013). Case Study of the Akosombo Hydroelectric Dam Environmental Sciences Essay. Accessed 20.11.15 http://www.ukessays.com/essays/environmental-sciences/case-study-of-the-akosombo-hydroelectric-dam-environmental-sciences-essay.php?cref=1
22. Ghana Wind Electric Potential. Accessed 10.12.15 **http://www.arrakis-group.com/energy/wp-content/uploads/2012/12/Ghana-Wind-Resource-Summary.png**
23. GRIDCo, 2010. POWER SYSTEM ENERGY CONSULTING: GHANA WHOLESALE POWER RELIABILITY ASSESSMENT 2010. Accessed 12.11.15 http://www.gridcogh.com/media/photos/forms/relassessment/2010_GRIDCo_Reliability_Assessment_Report.pdf
24. Guide to Electric Power in Ghana, 2005. Accessed 11.1115 http://www.beg.utexas.edu/energyecon/IDA/USAID/RC/Guide_to_Electric%20Power_in_Ghana.pdf
25. Gyamfi S, Mawufemo M. Sinisa D., 2015 Improving Electricity Supply in Ghana – The potential of renewable energy. Accessed 12.11.15 http://www.researchgate.net/publication/271118063_Improving_electricity_supply_security_in_GhanaThe_potential_of_renewable_energy
26. IAEI, 2012 COUNTRY NUCLEAR POWER PROFILE GHANA. Accessed 22.12.15 https://cnpp.iaea.org/countryprofiles/Ghana/Ghana.htm
27. World energy outlook, 2004. Accessed. 22.12.15 http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2004.pdf

`

28. IMANI Events, 2014. The Energy Crisis In Ghana: Impact And Solutions. Accessed 3.12.15 http://event.imanighana.com/the-energy-crisis-in-ghana-impact-and-solutions/
29. Inter Academy Council, 2007. Lighting the way towards a sustainable energy future. Accessed 4.11.15. http://www.interacademycouncil.net/File.aspx?id=24548
30. Investopedia, 2014. Accessed 20.10.15 http://www.investopedia.com/terms/d/developedeconomy.asp#ixzz3l8q4Iqmn
31. Journal of Energy Volume, 2015. Accessed 2.11.15 http://www.hindawi.com/journals/jen/2015/965825/
32. Lom A, 2013. Energized thinking: Ghana's renewable energy regime. Accessed 3.12.15 http://www.kwm.com/en/uk/knowledge/insights/energised-thinking-ghanas-renewable-energy-regime-20131121
33. Marful S. S., 2009. Security of electricity supply in Ghana. Accessed 6.11.15 file:///C:/Users/Joe/Downloads/cepmlp_car13_63_868500920.pdf
34. Mustapha I., 2015. The Best Mix of Power: The Way Forward For Ghana. Accessed 13.11.15 http://thechronicle.com.gh/the-best-mix-of-power-sources-the-way-forward-for-ghana/
35. NV energy, 2004. Accessed 5.11.15 https://www.nvenergy.com/kids_conservation/learn/make.html
36. OTA, 1991. Energy In Developing Countries. Accessed 22.10.15 https://www.princeton.edu/~ota/disk1/1991/9118/9118.PDF
37. Parliamentary office of Science and Technology 2002. Accessed 20.10.15 http://www.parliament.uk/documents/post/pn191.pdf
38. Power Africa, 2015. Investment Brief For The Electricity Sector In Ghana https://www.usaid.gov/sites/default/files/documents/1860/Ghana%20_IG_2015_05_03.pdf
39. Solar and Wind Energy Assessment (SWERA) Ghana. Accessed 5.12.15 http://www.energycom.gov.gh/downloads/Technical%20Reports/SWERA%20-%20National%20Report.pdf

`

40. The Power Crisis in Ghana: Analysis of the Causal Factors from the Perspectives of Public Officials . Accessed 18.10.15 http://graphic.com.gh/features/opinion/39140-the-power-crisis-in-ghana-analysis-of-the-causal-factors-from-the-perspectives-of-public-officials.html#sthash.E4WY5kbk.dpuf
41. The World Bank Group, 2015. Accessed 4.11.15 http://www.worldbank.org/mdgs/environment.html
42. VRA, 2010, Abridged Report. 2008 Volta River Authority http://www.vra.com/Publications/Accounts/vra_annual_report2009.pdf
43. VRA, 2015. Power Generation: Facts & Figures. Accessed 13.11.15. http://www.vra.com/resources/facts.php
44. Water Technology, 2015. Accessed 18.11.15 http://www.water-technology.net/projects/bui-dam-hydro-power-ghana/
45. World Bank, 2013. Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge. Accessed 13.11.14 https://openknowledge.worldbank.org/bitstream/handle/10986/16264/796560WP0P13140Box0377384B00PUBLIC0.txt?sequence=2

`